



# ***F-35 Pollution Prevention Activities***

**ESTCP/SERDP Surface Finishing and Repair Workshop  
26 February 2008  
Tempe, Arizona**

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# Agenda

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- ***What is F-35***
- ***Pollution Prevention (P2) Background***
- ***P2 Implemented System Solutions***
- ***P2 Solutions in Work***
- ***P2 Solutions Offering More Opportunities for Near Term F-35/ESTCP Partnerships***



# What is Joint Strike Fighter ?



**F-35A**



**Conventional  
Take Off Landing  
(USAF)**

**F-35B**



**Short Take Off  
Vertical Landing  
(USMC and UK)**

**F-35C**



**Carrier Variant  
(USN)**





# F-35 ESH Requirements

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- **Contract Data Deliverable List CDRL-001  
Air System Lifecycle Plan**
  - ***Hazardous Materials Reduction/Elimination Initiatives***
    - Identified and Controlled in Detailed Plan 2YZA00049  
Hazardous Materials Management Plan
  - ***Demilitarization/Disposal Plans***
    - Demilitarization/Disposal Plan 2YZA00102
- **Contract Statement of Work Commits  
LMAero/NGC/BAES to a Hazardous  
Materials Management Plan and Formal  
Working Group**



# The Continuing Sustainability Challenge and Interaction with Design for Environment (DfE)



- **LMAero Solved the Easy-To-Do Material/Process Substitutions on Previous Programs**
  - *Low Hanging Fruit*
  - *Typically Focused on Employee Exposure During Manufacturing*
- **Now the Challenge is to Find Material Substitutions That Reduce Life-Cycle Expense, i.e. Sustainability**
  - *Focus on Customer Maintainers Exposure During Operation, Maintenance, Depot Overhaul, Deactivation, Demilitarization, Disposal*
  - *Awareness of Hazmat Liability to Sub-tier Suppliers due to Current and Future Regulations*
  - *Reduce Life Cycle Cost Impact through Hazmat Minimization*
  - *This Results in the Design for Environment (DfE) Approach*

***Identify the Goal and Force the Solution***

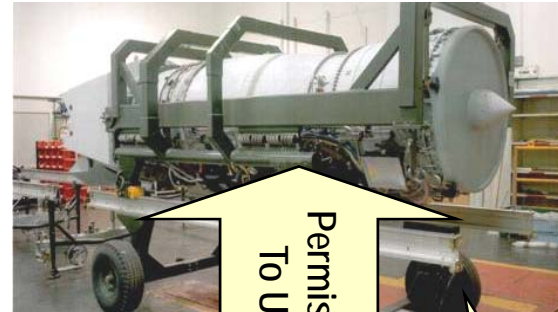
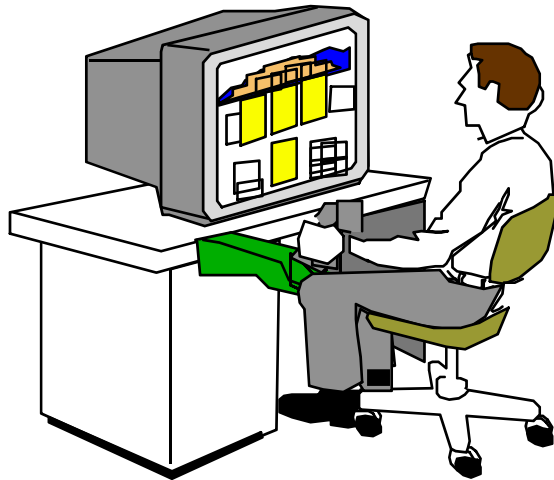


# Hazardous Materials Control Approach – Controlled by HMMP and M&P



*Support Equipment Design*

**Airframe/  
Subcontractor  
Design**



**NEPA/Conformity  
Planning**



Permission  
To Use

Permission  
To Use

Emission Impacts  
New Limitations

**Restricted  
Materials**

**Approved  
Materials**

Adopt New  
Requirements

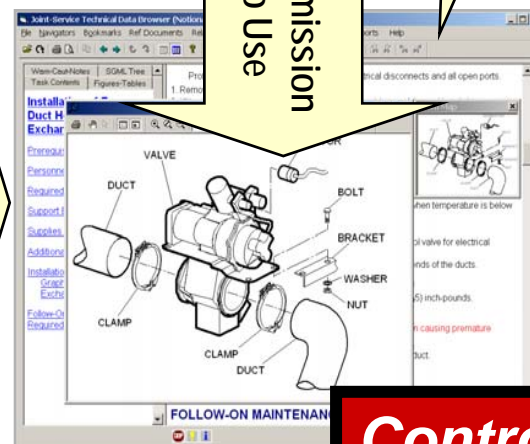
**Tech Data**

Permission  
To Use

Controlled by  
Tech Data



**Supply**



**Partner Country  
Regulation Research**

**Control Materials on Program**



# System Solutions

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## **System Changes and Improvements Implemented on F-35 With Demonstrable Pollution Prevention Benefits**



# Key DfE Technology – No Cadmium Fasteners



- **Traditional Aircraft Use Thousands of Steel Fasteners with Cadmium Plating**
  - *Cadmium provides corrosion protection and lubricity*
  - *Exposes Maintenance Workers to Cadmium During Depainting Because They Grind the Old Coatings Off*
  - *Several Thousand Dollars per Year for PPE and Longer Grinding Time Due to Occupational Limits*
- **JSF Uses Titanium or Stainless Steel Fasteners**
  - **No Cadmium**
    - Except for Three Locations with no Drop-in Replacement (QAD, SFD, Gun)
  - **More Expensive Up-front But Less Life Cycle Cost**



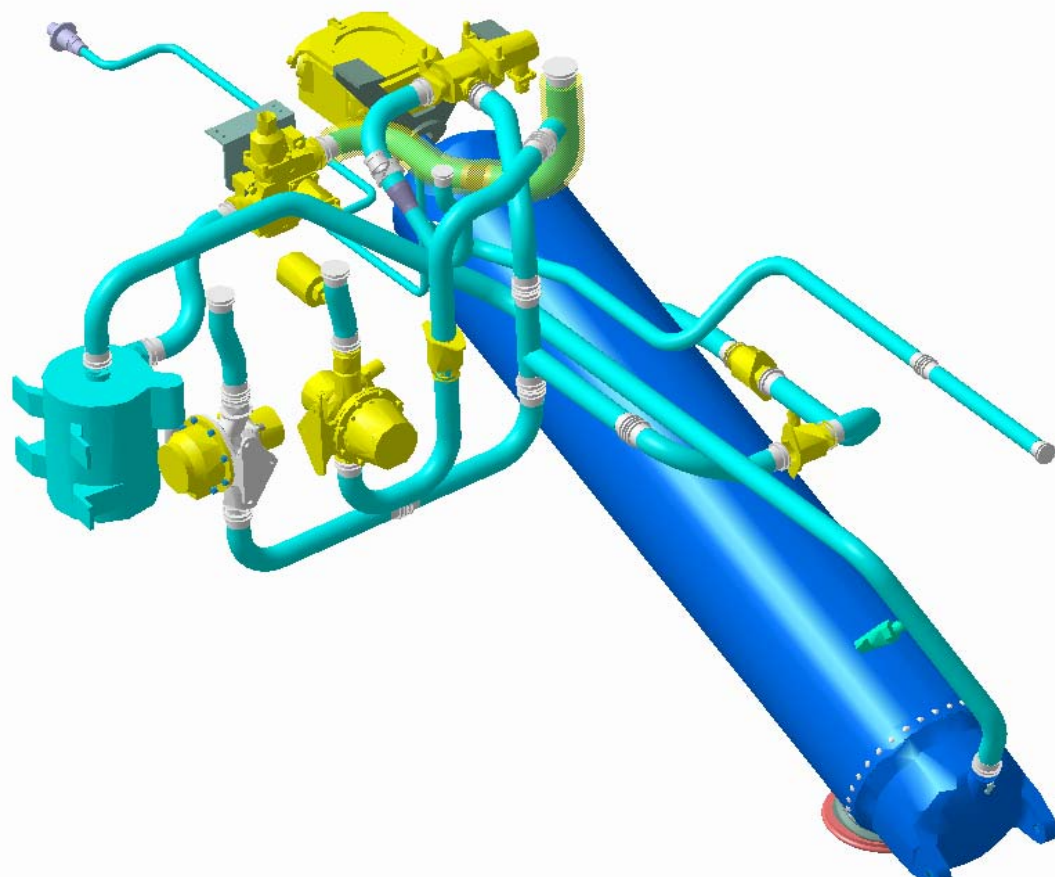
***Reduces Up/Down Stream ESH Impact***



# Key DfE Technology - OBIGGS



- ***Traditional Military Aircraft Used Halon 1301 (ODC) to Provide Fire Protection to Fuel Tanks***
  - ***Empty Fuel Tank Volume Must be Filled with Inert Gas to Prevent Fire/Explosion from Bullets/Shrapnel***
- ***On-Board Inert Gas Generating System (OBIGGS) Replaced Halon 1301***
  - ***Filters out Oxygen from Ambient Air to Create Nitrogen Enriched Air Suitable for Fuel Tanks***
  - ***Military No Longer Required to Maintain Halon Stockpile for Wartime Fuel Tank Inerting***



***No More Halon Stockpiles***



# Key DfE Technology - OBOGS

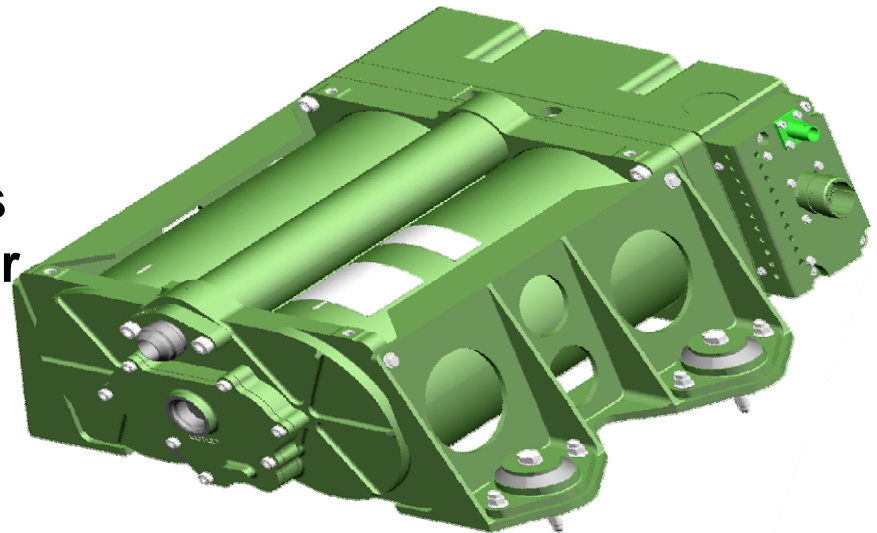


- ***Traditional Aircraft Carried the Pilots Oxygen Supply in Liquid Oxygen Tanks***

- ***Liquid Oxygen will Trigger Rapid Combustion of Any Dirt or Contaminates in the Supply System***
- ***Supply System Must Be Perfectly Clean***
- ***Best Cleaning Solutions Freon CFC-113 and HCFC-141b***

- ***On-Board Oxygen Generating System Replaced Liquid Oxygen***

- ***Produces Oxygen-Rich Breathing Gas From Engine Bleed Air Using Molecular Sieve Technology***
- ***No Exotic Cleaning Solutions***
- ***Military No Longer Required to Stockpile Freon for Oxygen System Cleaning***



***No More Freon Stockpiles***

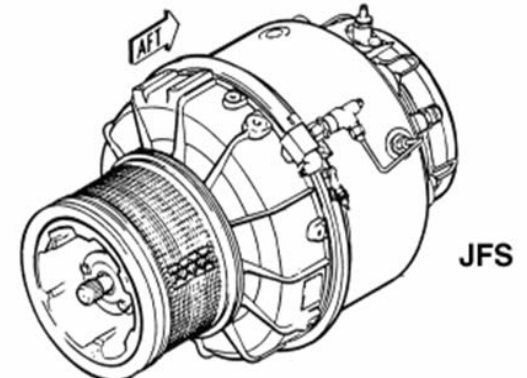


# Key DfE Technology - IPP



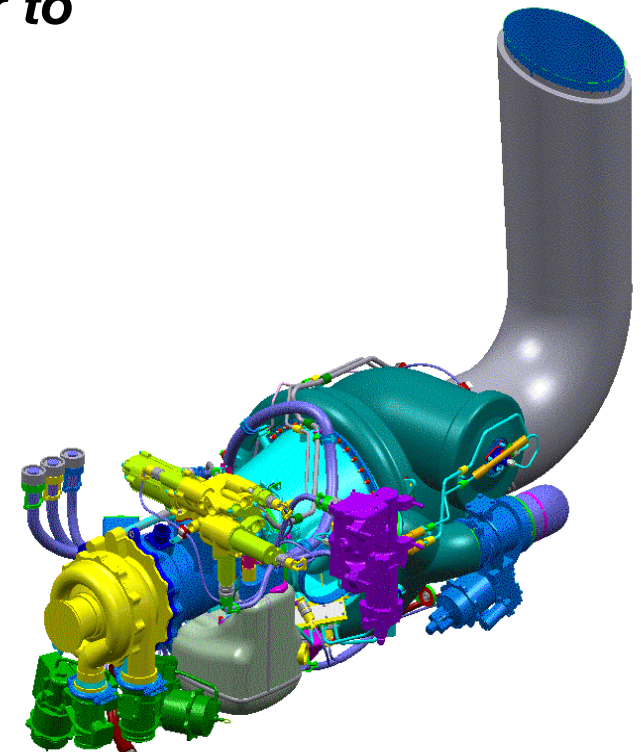
- ***Traditional Military Aircraft Contain An Emergency Power Generation System to Restart Failed Engine at Altitude***

- ***Some Systems Like F-16s Used Hydrazine***
- ***Unstable, Toxic, Dangerous Fluid Produces Gas to Turn a Turbine and Generate Enough Power to Restart Engine***



- ***Integrated Power Package (IPP) Replaces Hydrazine System***

- ***Small Turbine Engine Integrated with Other Vehicle Cooling/Heating Systems***
- ***Basically a Small Jet Engine***
- ***Easy to Start/Stop, No Hydrazine, No Leaks***



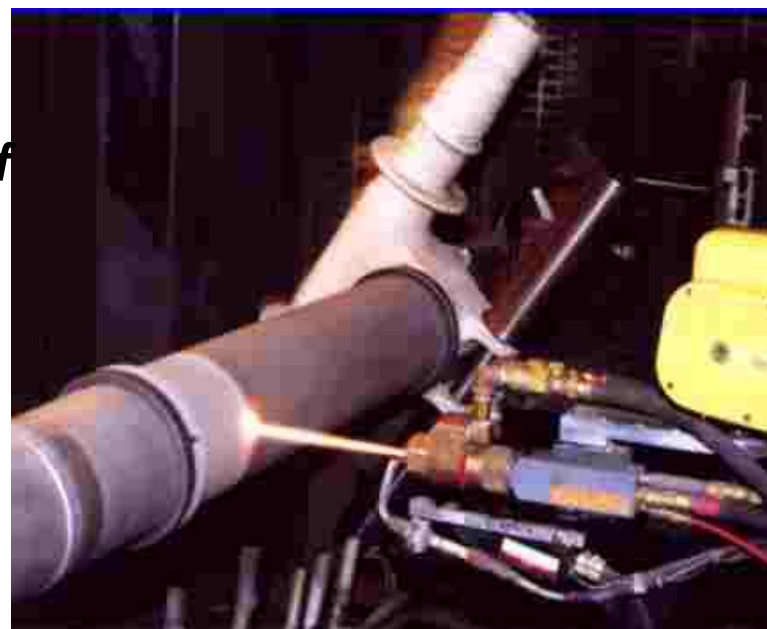
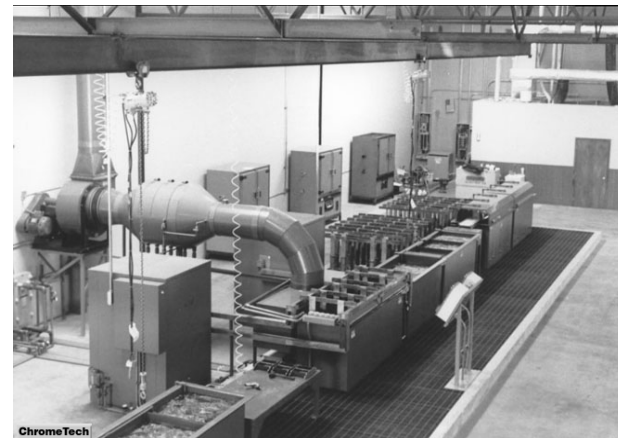
***No More Hydrazine Hazards***



# Key DfE Technology - HVOF



- **Traditional Aircraft Landing Gear and Other High Wear Surfaces were Chrome Plated**
  - **Chrome Plating Bath Environmental Liability**
  - **High Life Cycle Cost:**
    - **Requires Stripping/Replating every 3-5 Years**
    - **Military Services Must Have Plating Facilities**
    - **Replating Takes 2-3 Months**
    - **Requires Large Quantities of Spares**
- **High Velocity Oxygenated Fuel (HVOF) Technology**
  - **High Velocity High Temperature Stream of Powder Shot Onto Part Surface Forming Hard Impervious Wear-Resistant Coating**
  - **Long Life – Minimal Maintenance**
  - **Ultra-Smooth Superfinish Extends Life From Seals That Rub Against HVOF Coating**
  - **Standard Coating for All JSF Actuators, Wear Surfaces, Landing Gear**



**No More Chrome Plating**

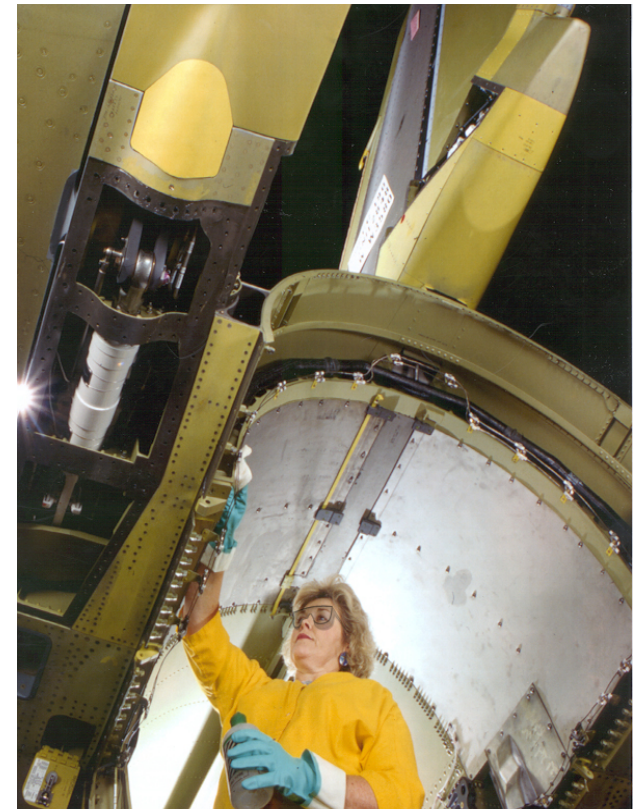


# Key DfE Technology – ODC Free Manufacturing



- ***Traditional Aircraft Fabrication Aids, Sealants, and Cleaning Solutions Often ODC-Based***
  - ***Good Cleanliness and Efficient Product Delivery***

- ***LM Replaced All ODC-Containing Products in 1995***
- ***No Class I/II ODCs Allowed on F-35 to Date***



***No More Ozone Depletion***



# Key DfE Technology Non-Chrome Primer



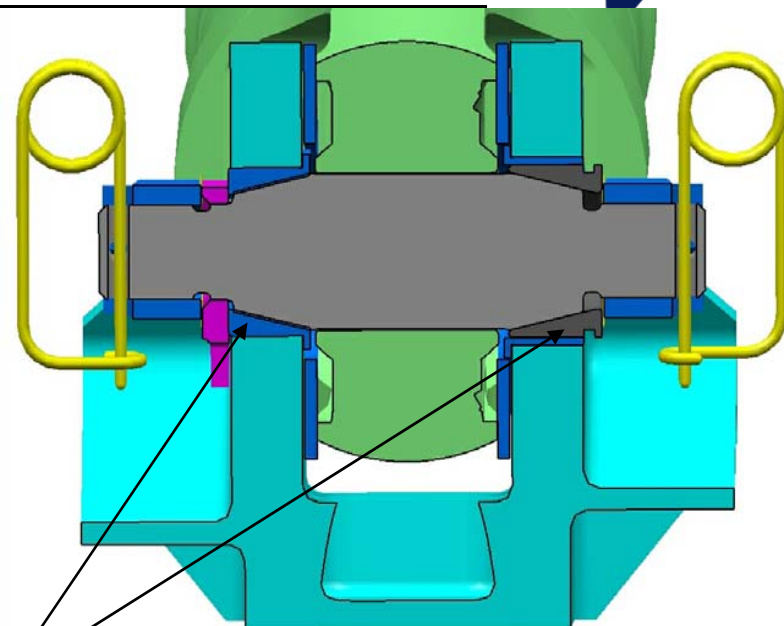
- **Approved Deft 44GN098 as F-35 Structural Primer**
  - ***BF-1 Effectivity (First STOVL)***
  - ***Fully Implemented on Airframe by BF-4***
    - Implementation on System Suppliers Voluntary to Avoid Costs
- **LM Aero and Northrop Grumman Performed Four Batch Verification**
- **Additional Compatibility with Exterior Finishes and Materials**
- **Qualified to LMA-MR003 Primer Specification**
  - ***Equivalent to Mil-PRF-85582***
- **NAVAIR Completed Qualification to Mil-PRF-85582**



# Key DfE Technology - Copper-Beryllium Bushing Replacement



- Copper-Beryllium (Cu-Be) Bushings Added to LMAero Restricted Materials List February 2004
  - *F-35 Technical Mgmt Concurred with Action Plan to Identify Locations and Develop Alternative Material Where Feasible*
- Typically Used for Flight Control Actuators and Other High Load Environments
  - *350+ Specific Locations*
  - *Switched to Other Materials for Many Applications*

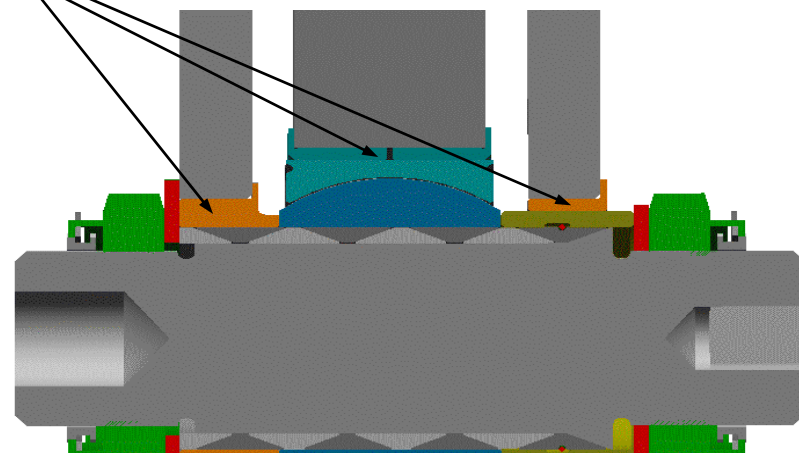


Horiz Tail Actuator

Cu-Be Bush

Main Landing  
Gear  
OutBoard  
Trunnion Fitting

Horiz Tail  
Inboard Hinge



**Rapidly Qualify/Implement New Materials**



# Bushing Replacement Lab Testing



- **F-35 Evaluation of Alternative Materials**
  - *ToughMet, Nitronic 50/60, 304/HBN, SBIR Developed, etc..*
  - *Phase 1 Completed Tensile, Compression, Bearing, and Shear*
  - *Phase 2 Completed Wear and Galling*
  - *Phase 3 Completed Elevated Temp Tensile*
  - *Phase 4 Completed SCC and Salt Fog exposure*
  - *All F-35 Bushings <2.5"Ø Switched to Cold Worked Nitronic 60*
  - *Phase 5 test plan Evaluating Installation Issues*
- **ASC PP3010 FY05-06 Funding**
  - *Subscale Testing and Implementation*
- **Materials Affordability Initiative (MAI)**
  - *25/75 Contractor/Government Cost Share with LM/Boeing/BrushWellman*
  - *Phase III Advanced Screening and Toughmet "S" Basis Generation*
  - *Phase IV Toughmet "A/B" Basis Generation, Fatigue and Fracture, Installation*
  - *Phase V Implementation Studies*

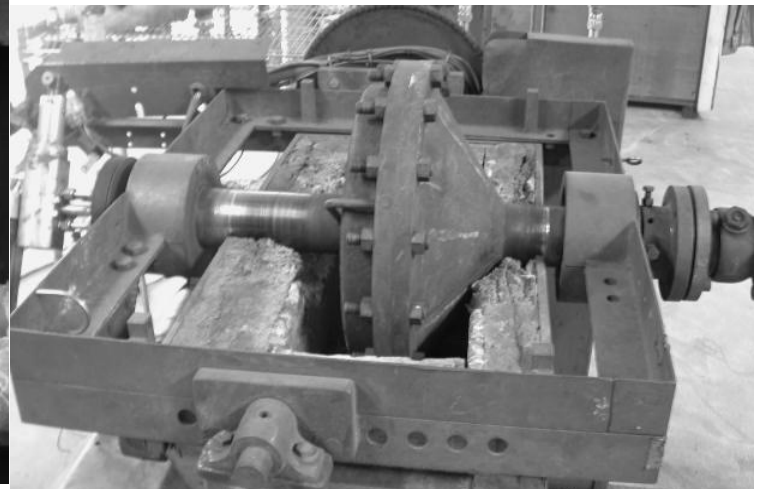
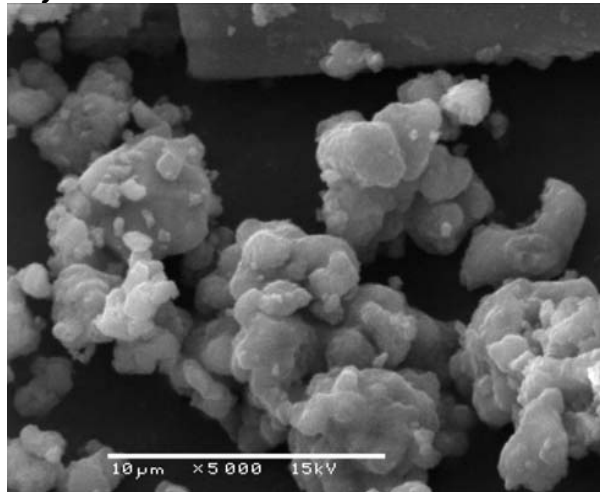




# Key DfE Technology - Material Disposal



- **CDRL A001 Requires Disposal Plan**
- **No Available Methods for Composites/Low Observable Materials**
- **Need Recycling Alternative with Beneficial Reuse to Avoid RCRA HazWaste Designation for Disposal**
- **Phase II Air Force SBIR LO Coating Destruction**
  - Phase I Fluidized Bed Reactor Concept Demonstrated Complete Breakdown of Materials and Conversion to Calcium Carbonate
- **F-35 Participating in Phase II**
  - *Provide Materials, Lab Verification of Destruction*
- **ESTCP Scale Up Assistance?**



***Eliminate Composite Disposal Uncertainty***



# Key DfE Technology - Corrosion Detection



- **F-35 Needs Low Budget Device to Solve Several Issues**
  - *Corrosion Detection, Locate OML Panel Edges and Fasteners, Detect Fluid Leaks, Inspect Composite Material Beneath Several Coating Layers, Verify Coating Thickness*
- **Existing Phase II SBIR Developed Microwave Corrosion Detection Device**
- **F-35 JPO ESH Sponsored Phase II Extension and Phase III Commercialization**
  - *LMAero F-35 Generating Reqmts*
- **P2 Benefit – Reduce Scheduled (non-necessary strip/repaint cycles) Coating Maintenance, Minimize Coating Damage During Event Maintenance**



***Avoid ESH Impact of Needless Coating Rework***



# Future ESTCP Cooperation

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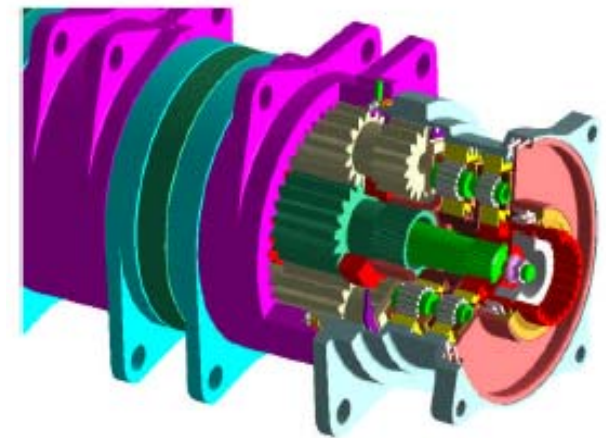
## ***How F-35 and ESTCP Can Continue to Work Together and Expand Work to Enhance Value***



# Key DfE Technology - Cadmium Plating



- ***Traditional Aircraft Steel Parts Protected From Corrosion by Cadmium Plating***
- ***Alternative Technologies Under Development***
- ***ESTCP Funded S-53 High Strength Stainless Steel Dem/Val Program on F-35 RGAs***
  - ***Risk Reduction Phase Underway by Fabricating One RGA 'Set' and Fatigue Testing***
  - ***LMAero/BAES Studying Corrosion Performance Enhancements***
  - ***Full Demonstration Starts 2007***



*Rotary Gear Actuators*

***Eliminate Cadmium Plating***



# Key DfE Technology - Gap Fillers



- LO Aircraft Require Gap Fillers Between Exterior Panels
- Maintainer Exposure Issue During Panel R&R Due to Sanding/Grinding Filler
- F-35 Studying Alternative Materials
  - *Northrop Grumman Awarded AFMC P2 R&D Program*
    - Non-nickel Alternatives
  - *Other Internal R&D Projects*
- If Successful Alternative Found, Can ESTCP Assist with Cross-Program Qualification/Implementation?
  - *Unique Program Qualification Requirements will Drive Cost*

***Improved Performance Less ESH Impact***



# Summary

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- ***F-35 Largest DoD Weapon System Acquisition Program***
- ***Replaces Several Legacy Aircraft Worldwide***
- ***Operates Under Comprehensive ESH Management and Hazmat Control***
- ***Conducts Aggressive Pollution Prevention and Material Substitution Activities Focusing On Life Cycle Cost Reductions***
- ***Integrates Partner Country Requirements into Program***